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CLINICAL COMMENTARY

SHOULDER POSTERIOR INTERNAL IMPINGEMENT IN THE OVERHEAD ATHLETE

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ABSTRACT

Posterior internal impingement (PII) of the glenohumeral joint is a common cause of shoulder complex pain in the overhead athlete. This impingement is very different from standard outlet impingement seen in shoulder patients. Internal impingement is characterized by posterior shoulder pain when the athlete places the humerus in extreme external rotation and abduction as in the cocking phase of pitching or throwing. Impingement in this position occurs between the supraspinatus and or infraspinatus and the glenoid rim. Understanding regarding this pathology continues to evolve. Definitive understanding of precipitating factors, causes, presentation and methods of treatment have yet to be determined. A high index of suspicion should be used when attempting to make this diagnosis. This current concepts review presents the current thinking regarding pathophysiology, evaluation, and treatment of this condition.

Keywords: Glenoid impingement, internal impingement, posterior impingement, throwing shoulder

Level of Evidence: 5

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BACKGROUND AND PURPOSE

Non-traumatic shoulder pain in the overhead athlete is an incredible diagnostic challenge because it can occur due to many reasons. Thus, pain that occurs with overhead activity is difficult to identify and diagnose. Pathologic contact between the margin of the posterior glenoid and the posterior tendons of the rotator cuff that face the articular surface of the glenohumeral joint is known as posterior internal impingement (PII).[1-3] The typical patient most likely to present with PII is a younger, active, overhead athlete.[4] Biomechanics of overhead throwing require the shoulder glenohumeral joint (GHJ) to withstand tremendous forces when the athlete pushes the limits of extreme external rotation and achieves rotational velocities of up to 7,000 degrees per second.[5] PII is characterized by pain in the posterior aspect of the GHJ of overhead throwing athletes during the late cocking phase of the throw where the GHJ is in a position of full external rotation and abduction of at least 90 degrees. The pain occurs due to compression of the supraspinatus and infraspinatus tendons by the posteriorly rotated greater tuberosity of the humeral head against the posterior/superior portions of the glenoid. This occurs when the humeral shaft moves posteriorly beyond the plane of the body of the scapula during the cocking position of throwing.[6] When the body of the scapula and the humeral shaft fail to remain in the same plane of movement during the cocking phase of throwing, encroachment of the rotator cuff tendons between the humeral head and the glenoid rim may cause PII. The movement of the humerus posterior to the plane of the body is commonly called "hyperangulation".[7] Because PII is a common cause of shoulder pain in the overhead throwing athlete it is important for clinicians to be able to accurately diagnose this condition. A high index of suspicion of PII, and a thorough history and physical examination will assist any clinician in assessing GHJ pain and differentiating between PII and other shoulder pathologies. Evidence does exist that contact occurs between the glenoid and rotator cuff in asymptomatic shoulders.[8-9] However, overhead athletes such as pitchers perform high stress, high velocity throwing actions repetitively over the course of a season, during which specific osseous and soft tissue adaptations may occur. Adaptive anatomic changes in throwers that can lead to internal impingement include glenohumeral internal rotation deficit (GIRD), increased humeral and glenoid retroversion, acquired glenohumeral anterior/posterior instability, scapular weakness or motor control deficits (specifically lack of scapular retraction strength), and concomitant rotator cuff weakness.

The chronic repeated compression or impingement can cause fraying of the undersurface of the supraspinatus and infraspinatus tendons as well as some fraying of the superior labrum which can lead to superior labrum anterior to posterior (SLAP) lesions. The authors of this manuscript feel strongly that is functional disturbances such as subtle GHJ instability, restricted GHJ range of motion, and scapular dysfunction can cause or contribute to the development of PII.

EXAMINATION

A thorough history is the first step in any patient encounter. A patient with PII will often complain of a deep, poorly localized posterior shoulder pain or ache that typically occurs during the late cocking phase of throwing. However this syndrome can occur in athletes who utilize similar motions of extreme external rotation and abduction such as a tennis and volleyball players. The pain often radiates to the lateral arm over the deltoid muscle. Pain to palpation can be found directly underneath the posterior lateral portion of the acromion. Pain is often insidious in onset and patients rarely have one specific mechanism of injury that they associate with the onset of pain. Patients generally deny numbness, pallor, or paresthesias in the arm so the presence of these complaints should make the clinician suspicious of other pathology.

An adequate physical exam is essential to making the appropriate diagnosis in a patient with shoulder complex pain. The full cervical spine and shoulder girdle must be visualized in order to perform an adequate examination. It is not uncommon for throwers to have increased muscle mass in the dominant shoulder that may cause an appearance of asymmetry. This is a common adaptive alteration that occurs due to repetitive throwing and should not be seen as pathologic. Due to laxity changes that occur from throwing the dominant shoulder may also sit slightly lower than the non-dominant shoulder (Figure 1).

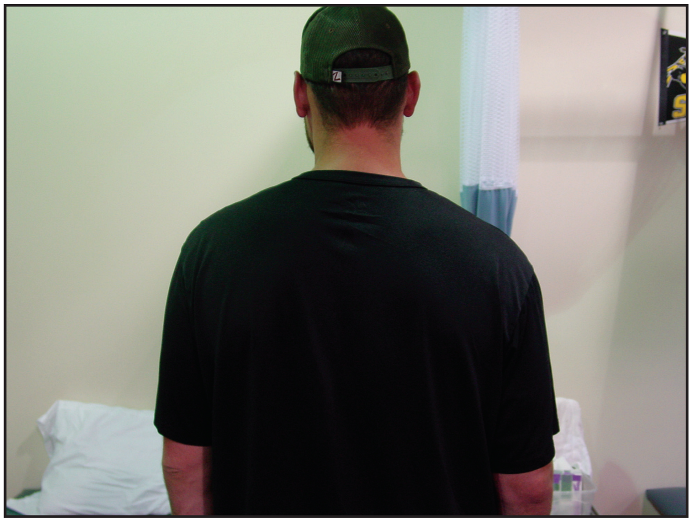

Figure 1. *Laxity changes in the dominant arm of the throwing shoulder demonstrate handedness or a lower more protracted shoulder compared to non dominant side.*

Figure 2. *Glenohumeral internal rotation deficit as demonstrated by a significant lack of internal rotation on the dominant shoulder when compared to the non dominant shoulder.*

Some shoulder complex pain is actually radicular in nature and originates in the cervical spine; thus a good shoulder complex exam always starts with screening of the cervical spine. The clinician should assess range of motion of neck and perform a Spurling's test to assess for pain or paresthesias that radiate into the arm. Once cervical spine pathology is ruled out, the clinician can direct their attention to the GHJ.

Inspect the patient for any changes in skin such as ecchymosis, erythema, swelling, or pallor. Palpate the bony and muscular structures of the shoulder girdle and take note of any asymmetry in bony anatomy and in muscle definition. Marked asymmetric muscle hypertrophy or atrophy may be indicative of additional shoulder pathology and should be evaluated thoroughly. Strength and sensation of the upper extremity should be assessed as well as distal pulses and capillary refill. The next step in physical exam is to observe the patient in active range of motion including forward flexion, abduction, and internal and external rotation at 0 and 90 degrees. Patients with significantly impaired active range of motion should have their passive range of motion (and end feels) assessed in order to help differentiate muscular weakness from other joint pathology within the GHJ, such as adhesive capsulitis or advanced osteoarthritis, which will limit both active and passive range of motion. Next, pay special attention to the internal and external range of motion in the affected and unaffected shoulder. GIRD is defined as a lack of internal rotation and excessive external rotation in comparison to the non-dominant shoulder. Many overhead athletes develop anatomic adaptions to their humeral anatomy that causes the affected arm to have an increase in external rotation and decrease in internal rotation at 90 degrees when compared to the non-dominant arm (Figure 2). Typically, the dominant shoulder has 10-15 degrees more external rotation, and 10-15 degrees less internal rotation than the nondominant shoulder.[10] However, as long as the total arc of rotation approximates 180 degrees on both sides, this is not always considered pathologic. If, however, the lack of internal rotation causes the total arc of the affected shoulder to be less than 180 degrees or an equal amount as the unaffected shoulder, the diagnosis of GIRD is likely. Researchers suggest that this loss of internal rotation comes from both humeral and glenoid retroversion and increased external rotation from capsular remodeling;[11-12] all of which can be a result of years of participation in the overhead throwing motion. Wilk has shown that professional baseball pitchers with GIRD are almost 2 times as likely to be injured as those without.[13]

It is important to observe the patient's shoulder elevation range of motion while facing him or her in order to assess for asymmetry, but also extremely important to observe his range of motion from behind, while paying special attention to the dynamic motion

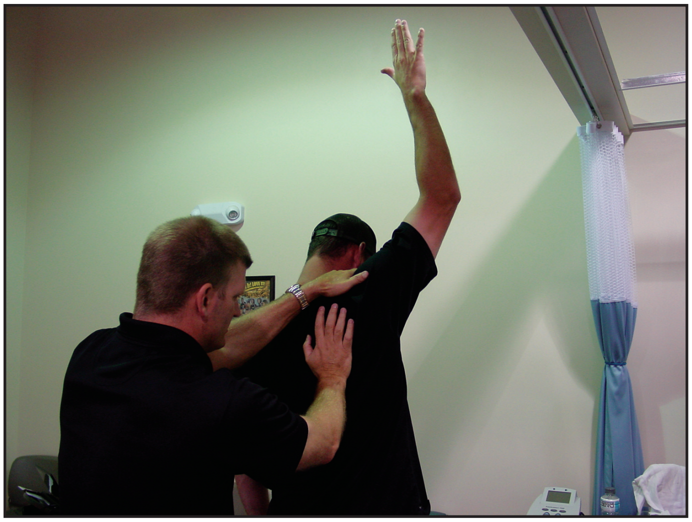

Figure 3. *The Kibler scapular retraction test. In this test the scapula is stabilized on the posterior thoracic wall as the athlete elevates the shoulder demonstrating less symptomatic and improved shoulder elevation.*

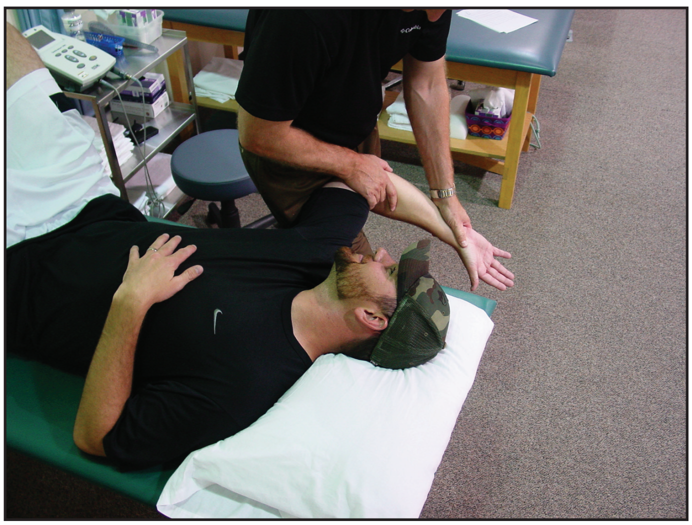

Figure 4. *Jobe's subluxation/relocation test. Posterior pain found upon overpressure to end range external rotation in the 90/90 position that is relieved with an posterior force would indicate posterior internal impingement.*

of the scapula. Patients with outlet shoulder impingement will often be limited in forward flexion on the affected side with an inability to forward flex to the full 180 degrees. Additionally, these patients will often have unilateral (or bilateral) internal rotation of the scapula in which the medial border moves posteriorly, suggesting scapular stabilizing musculature strength or endurance deficits. If the clinician notes anterior tilt of the scapula, you may elect to stabilize the shoulder girdle by performance of the Kibler scapular retraction test.[14] This test is performed by using the forearm or hand of the examiner to compress the scapula against the ribs posteriorly and asking the patient to again attempt forward flexion (Figure 3). Patients often describe a more pain free, full range of forward flexion when the scapula is stabilized, which may indicate the condition of outlet (subacromial) shoulder impingement. The therapist may elect to also ask the patient to do a scapular pinch test by having the patient squeeze the scapulae together. Inability to hold that position for more than 15 seconds suggests weakness of the scapular retractors.[14] Overhead throwing athletes with internal impingement frequently have weakness of scapular retractors as compared to the scapular protractors which predisposes them to internal impingement pathology.

GHJ stability is the next important step in examination. Pitchers with internal impingement may often have subtle instability. This may be a very slight asymmetric laxity or microinstability, which may be hard to distinguish from a normal amount of increased laxity commonly seen in a thrower. To begin assessment for stability, while patient is seated, begin by checking for a sulcus sign that would indicate inferior laxity of the shoulder capsule. Next, lay the patient supine and assess anterior/posterior laxity of the shoulder by attempting to translate the humeral head anteriorly and posteriorly along the glenoid while performing an anterior and posterior load and shift test.[15] An examination test that may be more specific for microinstability is the Jobe's relocation test.[16] This test is performed with the patient supine with the arm in 90/90 position. Passive overpressure is performed, while in the maximally externally rotated position (Figure 4). If pain is produced the anterior humeral head is translated posterior in an attempt to decrease or remove pain. If the pain is reduced or eliminated with the posterior force on the humeral head, a positive test is indicated. The theory to explain the results of this test suggests that a posterior directed force decompresses a so-called "kissing lesion" that occurs between the rotator cuff and the posterior glenoid.[17]

DIAGNOSTIC IMAGING

Upon completing a thorough history and physical, a clinician may elect to obtain x-rays of the shoulder complex in order to assess bony anatomy that can contribute to the development of internal shoulder impingement. An adaptive changes that may occur

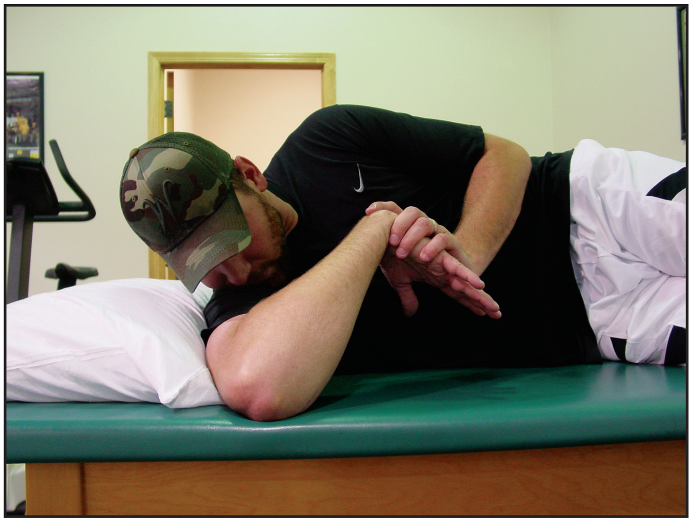

Figure 5. *Sleeper stretch done in side lying to mobilize the posterior shoulder.*

in a throwers shoulder includes the Bennet's lesion, an extra-articular ossification of the posterior capsule that occurs due to chronic strain on the pathologically tight posterior capsule in patients with GIRD.

Further imaging such as magnetic resonance imaging (MRI), computed tomography (CT) or musculoskeletal ultrasound provide little diagnostic information in a standard case of PII but can assess for complications of internal shoulder impingement and should be reserved for evaluation for use in suspected pathologies that may require surgical intervention, such as rotator cuff tear or labral injury.[18-22] In order to most accurately assess the joint for possible surgical intervention, it is prudent to obtain a magnetic resonance (MR) arthrogram with gadolinium contrast. It is important to remember that imaging is a helpful adjunct to making the diagnosis of internal shoulder impingement and its complications. The discovery of a labral or rotator cuff tear on imaging may or may not correlate with the patients' primary symptoms. Imaging findings must correlate with patient history, clinical symptoms, and examination findings. Halbrecht et al were among the first to notice (using non contrast MRI) that there was actual contact between the posterosuperior glenolabral complex in both the throwing and non-throwing shoulders of 10 asymptomatic baseball players, when placed in the position of abduction and external rotation.[23] Because this finding was seen in both shoulders it was considered a normal physiological occurrence. However, 4 of the 10 throwers had signal changes suggestive of tendinosis or delamination of the rotator cuff and 3 of the 10 demonstrated labral tears with paralabral cysts, despite being asymptomatic.[23] Miniaci et al also found that almost 80% of asymptomatic professional baseball pitchers demonstrated abnormalities of the labrum despite having no symptoms during throwing.[24] Therefore, extreme care should be taken when deciding whether surgery is the appropriate option for a patient with PII and should not be based on imaging alone.

TREATMENT

As with most shoulder conditions, non-surgical/conservative care should be attempted initially with the diagnosis of PII in the overhead athlete. Each of the following areas should be assessed 1) GIRD or loss of glenohumeral internal rotation range of motion, 2) lack of rotator cuff and scapular strength and endurance, 3) acquired glenohumeral anterior instability. These are all functional disorders that are typically treated with physical rehabilitation as compared to a structural problem that would require surgical intervention. Each of these disorders should be treated as potential contributors to PII. Although a cause and effect relationship between these 3 functional disorders and PII is not clear, they are probably interrelated and deserve attention during rehabilitation.[6]

Interventions for GIRD

Although some degree of GIRD is due to humeral torsion that will not be amenable to recovery, the component of lost motion that is due to either muscle or capsular tightness should be addressed, and may demonstrate substantial improvement in motion. Because this loss of motion comes from either muscle tissue or capsular tissue restrictions either stretching or joint mobilization techniques will be useful for gaining mobility.

Stretching techniques for the posterior shoulder include passive horizontal adduction and internal rotation movements to the glenohumeral joint that can be performed passively by a therapist or at home by the patient.[25] Stretching for the posterior shoulder can be done either sidelying or supine.[26-28] Sidelying techniques include the supine sleeper stretch in which the patient lies on the injured side with the shoulder in 90 degrees of forward flexion (Figure 5). While the scapula is stabilized by bodyweight

Figure 6. *Cross-arm stretch done in supine with assistance from therapist.*

on the table, glenohumeral internal rotation is done by passively stretching into further internal rotation as described by Burkhart et al.[27-28] This stretch can be done at various degrees of shoulder flexion in order to "fine-tune" the stretch. The sleeper stretch is not without problems. Proper technique ensures that the stretch discomfort felt is in the posterior shoulder. Pain that is reproduced in the anterior or superior portions of the shoulder should qualify as reason to discontinue this stretch. Stretching should then be re-attempted by reducing the intensity of the stretch, reducing the amount of elevation of the shoulder complex which may be creating excessive elevation of the humerus, or by altering the trunk position by rotating backward slightly which should reduce strain on posterior structures. Additionally, a therapist can perform internal rotation stretching from the 90/90 position in which passive overpressure is given (while control of the scapula is maintained) or contract relax techniques can be applied.

The cross-arm stretch can be performed in either a seated or supine position by the patient or by force imparted by a therapist (Figure 6). The supine position may be preferred by most as the scapula is better stabilized with help of bodyweight. Additionally in this position the therapist can either perform passive stretching or contract relax techniques.

There is some evidence that these forms of treatment are able to alter soft tissue and gain needed mobility restrictions. Laudner, Sipes and Wilson found that 3 sets of 30 second sleeper stretches significantly improved internal rotation range of motion compared to a control group of active baseball players.[29] McClure et al demonstrated significantly better results for increasing internal rotation ROM in subjects with restricted glenohumeral shoulder internal rotation by using the cross body stretch, as compared to using the sleeper stretch.[30]

Lintner et al used a combination of both the cross arm stretch and internal rotation stretching at 90 degrees of abduction to mobilize the posterior shoulder.[31] Professional pitchers who were placed on a stretching program for more than 3 years had greater internal rotation and total rotation range of motion in the dominant shoulder than those with less than 3 years of stretching.[31] There appears to be a progressive increase in both internal rotation and total arc of motion with the number of years in such a program.

Manske et al[32] found that the addition of joint mobilizations to the cross-arm stretch resulted in increases in internal rotation ROM after 4 weeks of intervention in subjects with restricted glenohumeral shoulder internal rotation ROM. This increase (stretching plus mobilization group improved 19°, stretching alone 14°, and controls 6°) although not statistically significant, may be clinically significant as the amount of rotation improvement required for a decrease of symptoms likely varies with each patient. Coincidently, after a 4-week washout period those that received joint mobilization treatments also kept the greatest amount of internal rotation ROM, demonstrating a possible preferred carry over effect of the intervention.

Interventions for Acquired Instability

Repetitive microtrauma sustained during high-demand overhead sports activities such as pitching a baseball or softball, swimming and gymnastics could create a gradual excessive stretching of the glenohumeral capsule, compromising its stabilization role leading to instability.[33] Furthermore, this "acquired laxity" in overhead athletes typically occurs near the capsules physiological limits resulting in instability.[34] An important concept when discussing acquired instability is that of stability afforded by the concavity compression which occurs when a convex objects is compressed into a concave surface.

Figure 7. *90/90 rhythmic stabilization exercises to increase strength and endurance of the rotator cuff muscles in a position that simulates throwing.*

Concavity compression occurs in the GHJ between a minimally concave glenoid fossa and the convex humeral head.[35] This concept is very useful for acquired instability especially in the mid ranges of motion where the glenohumeral capsule and ligaments are lax and where the rotator cuff muscles and long head of the biceps tendon have anatomically advantageous locations ideally suited to compress the humeral head into the fossa.[36-37]

It must be noted that most of the literature with regard to treatment of those with unstable shoulders is based more on clinical observation than on scientific evidence. Stability and mobility of the nonpathologic, asymptomatic shoulders require the synchronous functions of dynamic and static stabilizers that become dysfunctional in those with acquired instability. Shoulder instability may be viewed simply as any condition in which the balance of the various stabilizing structures is disrupted, resulting in increased joint translation and the development of clinical symptoms.[38] Therefore, rehabilitation for an overhead athlete with acquired instability must be aimed at improving rotator cuff and scapular strength, endurance, and neuromuscular control as described previously. By increasing cuff and scapular strength, there is a return of important force couples that allow for dynamic stabilization of the shoulder.[39] Because the rotator cuff muscles blend into the glenohumeral ligaments and joint capsule the concept of increasing dynamic ligament tension during cuff activity also applies to those with acquired instability.[40,41] As most of the rehabilitation to combat acquired instability requires strengthening and neuromuscular/motor control of rotator cuff and scapular muscles they will be discussed below.

Interventions for Rotator Cuff and Scapular Weakness/Dyskinesia

Most studies that have investigated scapular and rotator cuff muscle firing patterns have been performed using a host of normal healthy individuals. Findings of these studies are used when describing appropriate exercises for the patient with internal impingement. Although these studies that will be used to guide the selection of exercises for the rotator cuff and scapula did not utilize athletes with internal impingement, for purposes of this clinical commentary the assumption will be made that these exercises would likely be helpful for those with internal impingement. Although strengthening rotator cuff muscles will be described prior to scapular muscle strengthening, an integrated approach to strengthening both is typically indicated. However, there are times in which either the rotator cuff muscles or the scapular muscles may be affected to a greater degree at which time direction should be directed toward the most affected muscle group. If there is minimal to no irritability the athlete may begin with isotonic band exercises and completely skip gentle submaximal isometric exercises.

In general a good place to start strengthening of the cuff muscles is with gentle alternating isometrics can be performed with the shoulder in a static position.[42] These rhythmic stabilization exercises are performed by gently resisting antagonistic muscles in an alternating pattern are utilized to establish non painful rotator cuff muscle firing patterns.[43] Initial exercises such as these for the rotator cuff muscles are typically initiated in a supine position with the shoulder in approximately 20-30 degrees of scapular plane abduction and progressed to 90 degrees of elevation or more (still in the scapular plane) as the athlete tolerates (Figure 7). More progressive exercises can include performing these isometrics in greater ranges of either flexion or abduction or doing them in an upright position with the extremity in a closed chain position via hand placement on a wall.[44] Once the athlete is able to tolerate more progressive exercises,

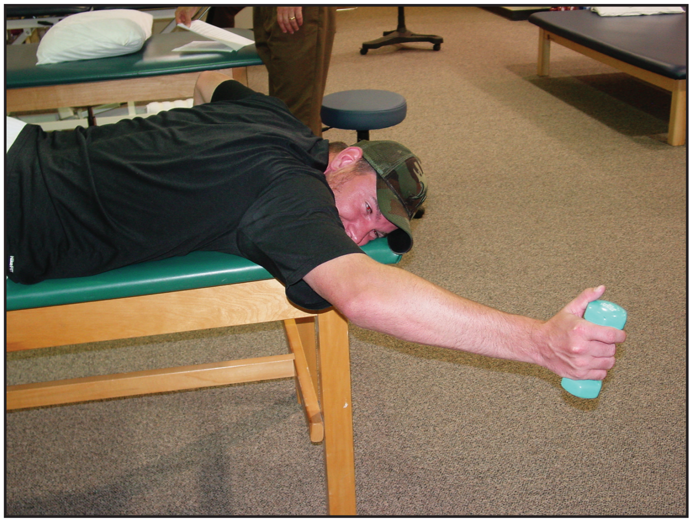

Figure 8. *Prone Blackburn exercises performed in 100 degrees of abduction and external rotation (thumb up).*

Figure 9. *Prone on elbows serratus strengthening exercise for early scapular strengthening.*

movement patterns with bands or dumbbells can begin. Jobe described elevation in the scapular plane with glenohumeral internal rotation, in the "empty can" position, as an exercises to strengthen the supraspinatus.[45] Due to the potential risk of impingement when performing scapular plane abduction in ranges higher than 90 degrees of elevation with arm in internal rotation the "full can" has been shown to be an excellent alternative with comparable muscle activity with much less risk of impingement.[46-49] Blackburn has described the prone full can, or horizontal abduction (100 degrees of elevation) with external rotation, as an exercise that facilitates high supraspinatus electromyographic activity (Figure 8).[50]

Figure 10. *Push up plus done with feet elevated to enhance cuff and scapular muscle recruitement.*

Because the infraspinatus and teres minor have very similar concentric muscle actions of externally rotating the humerus they can generally be exercised with the same movements. However, evidence has shown that the infraspinatus may be a more effective external rotator at lower angles of abduction, whereas the teres minor has more constant activity and can fire optimally throughout elevation range of motion.[51] Reinold and colleagues have demonstrated high electromyographic activity of the infraspinatus and teres minor with exercises such as side lying external rotation, standing external rotation in the scapular plane at 45 degrees of abduction, and prone external rotation in 90 degrees of abduction.[52] In addition to the exercises already described, several other exercises have been described by Townsend et al to activate rotator cuff muscles to a high degree.[53]

One of the most important muscles that are required to work optimally in the overhead athlete is the serratus anterior. The serratus anterior (SA) works in concert with the upper and lower trapezius to upwardly rotate the scapula during overhead movements. Most overhead lifts and push-ups effectively recruit the SA. Activity of the SA tends to increase linearly with the amount of elevation at the glenohumeral joint. This could include wall push-ups, push-ups in prone on elbows (Figure 9), push-ups in quadruped or standard push up positions. Uhl has shown high serratus activity when doing a push up with the lower extremities in an elevated position (Figure 10).[54] Exercises for the serratus early in the

Figure 11. *Punching type exercise for strengthening the upward rotation component of the serratus anterior.*

rehabilitation progression should keep the shoulders at 90 degrees of elevation or below to decrease risk of iatrogenic subacromial impingement. However in order to achieve higher activity one must eventually perform pressing or "plus" type motions above 120 degrees of elevation where the upward rotation component of the serratus can be called into action.[55] These motions can be performed in a "hugging" type motion or in a "punching" motion (Figure 11).

CONCLUSIONS

Internal impingement is a common condition in overhead athletes. This clinical commentary has offered readers a look into the theoretical causes of this pathology. The astute physical therapist considers PII as one of their differential diagnoses when examining the shoulder complex. Physical examination tests are helpful to determine pathology or make a differential diagnosis in those with posterior shoulder pain. Although imaging is not typically needed for assessment of internal impingement it does assist in ruling out other potential causes of posterior shoulder pain. Rehabilitation for PII should consist of several critical interventions including reversing GIRD in those with posterior shoulder tightness, creating improved dynamic stabilization of the GHJ through use of specific exercise techniques in those with hypermobility due to acquired instability, and developing neuromuscular control in those with scapular dyskinesis. Exercises should emphasize both scapular and rotator cuff muscle recruitment patterns in order to improve strength, endurance, and motor control.

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